Optik 127 (2016) 3474–3479

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Analysis of the calculation of the amplitude of accommodation

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ARTICLE INFO

Article history:
Received 27 July 2015
Accepted 8 December 2015

Keywords:
Amplitude of accommodation
Spectacle accommodation
Ocular accommodation
Push-up method
Near point

ABSTRACT

The push-up method is routinely used to measure the amplitude of accommodation. In this method the diopter value corresponding to the nearest point that the eye can focus is determined, wearing his neutralizing lens, but not the value of the maximum diopter variation that makes the eye.

The aim of this paper is to review the calculation described in the push-up method taking into account the real position of the near point of the eye.

In the subjective push-up method, it is calculated the reciprocal of the distance from the lens until the test object at this position of first, slight, sustained blur. We calculated the differences between this value and the ocular amplitude of accommodation, taking into account that the eye is really looking at the image of first blur through the neutralizing lens.

Experimental measurements were also taken to determine whether they were similar to theoretical values.

The results obtained by the two calculation methods compared were in general significantly different and the difference was greater for young people with high ametropy. The theoretical results were in agreement with the experimental ones.

According to the optometric information required must select the appropriate calculation method, since the values obtained in each of them are not comparable.

1. Introduction

The amplitude of accommodation (Am) is mathematically expressed as the dioptric difference between the far point (fp) and the near point (np) of the eye and it is related to the maximum power variation that can perform an eye [1].

The amplitude of accommodation is a measure of special interest in optometry because it is used to calculate the presbyopic addition and to establish if there is accommodative dysfunction. Therefore, it is an important magnitude for the optometrist when a lens type or vision therapy method must be decided upon. Measurement of the amplitude of accommodation influences the diagnosis of insufficient accommodation because this measure declines in these patients [2]. In patients who have undergone refractive surgery it is also important to measure the amplitude of accommodation as this varies postoperatively, being especially relevant for presbyopic patients [3]. Finally, the amplitude of accommodation is a measure used to validate accommodative intraocular lenses.

As it is well known, the amplitude of accommodation of a person is not constant throughout his life because decreases gradually over the years.

The measurements taken by Donders (1864), and the Hofstetter's equations (1950), are still used today as normal reference values in the population [1,4]. However, it seems that the normal values from these authors were obtained from measurements of emmetropic subjects or low ametropias. Hence, it is appropriate to reconsider whether the values shown in these tables can be taken as standard for all observers, i.e. emmetropes and ammetropes, based on the measurements of accommodation obtained from an optometric examination [5].

Although there are different methods to determine objective and subjective values of the amplitude of accommodation, in optometry, generally, it used Donders subjective method, it is called the push-up method and it is routinely used. Subjective methods are used in clinical practice because they do not require specific instruments and are performed quickly and easily. Several pilot studies have been done to determine the value of the amplitude of accommodation by different methods, and found that the values obtained by the push-up method provided higher values than other methods [6–12]. It is therefore important to evaluate how precise in the subjective measurement of the amplitude of accommodation and, if necessary, refine it.

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http://dx.doi.org/10.1016/j.ijleo.2015.12.029

The push-up method determines the diopter value of the position of the point first, slight, sustained blur with neutralizing lens. With this method it is obtained the value named by some authors as the “spectacle accommodation” but does not correspond to the value of the ocular accommodation [13]. Therefore, the push-up method does not provide information about the maximum diopter variation that the eye can perform, because it depends on the refraction.

The fact that both values can be considered the same or that both amplitudes can be similar could lead to misinterpretation. In this paper we will check what differences exist between both values and analyze the need for changes in the method of push-up depending on the measure that it is required obtain.

2. Methods

2.1. Theoretical calculations

In the subjective push-up method, the amplitude of accommodation is measured with the ammetropia corrected by spectacle lenses. In the measurement procedure, the patient observes a finely detailed test object which is brought closer to the patient's eye until the detail just begins to blur. The reciprocal of the distance from the test object at this position of first, slight, sustained blur to the spectacle plane in meters (np_D^G) represents the amplitude of accommodation (in diopters) [14–18] or what some authors call “spectacle accommodation” [13].

$$Am_{push\text{-}up} = -\frac{1}{np_D^G} \tag{1}$$

In this method the fact that the patient is not accommodating at the plane where the test object is situated is not taken into account; the observer is actually accommodating at the distance where the lens forms the image of the test object. Therefore, the push-up method of calculation does not determine the maximum accommodation of the eye have, especially in ametropia.

It is known that when an object is observed through a lens, the final image that forms on the retina is not obtained directly from the object, as can be seen in Fig. 1. First, the intermediate image of the object that the lens produces must be taken into account, since it is this image that will be the object for the eye [13,19].

Applying geometrical optics equations to the optical system of the eye, it is possible to calculate the exact position of the intermediate image (x_{eye}). Therefore, to determine the accommodation that the subject employs at this position, it is only necessary to apply the mathematical expression used to calculate the accommodation of the eye at a certain distance [1]:

$$A = R - \frac{1}{x_{eye}} \tag{2}$$

R is the refraction of the eye and x_{eye} is the distance from the eye to the intermediate image in meters. If x_{eye} corresponds to the near point of the eye, the amplitude of accommodation of the eye may be calculated (ocular accommodation). From the steps above, we can find a formula which allows the accommodation of a corrected eye at a given distance (A_N) [1]:

$$A_N = \frac{X(1+\delta_V R)}{\delta_V^2 RX - 1} \tag{3}$$

In this equation X represents the reciprocal of the object distance from the eye in diopters ($X = 1/x$) and δ_V is the distance from the lens to the eye in meters (see Fig. 1) [1].

Applying the above expression taking x as the distance from the eye to the first blur point in meters (np_D), we can calculate the value of the ocular accommodation (Am_{eye}).

$$Am_{eye} = \frac{P_D(1+\delta_V R)^2}{\delta_V^2 R P_D - 1} \tag{4}$$

P_D ($P_D = 1/np_D$) is the reciprocal of the distance of the first blur point from the eye in diopters determined by the push-up method.

Since in practice the distance from the eye to the test object when the observer reports the first blur can be directly measured, the amplitude of accommodation of the eye may be directly calculated using Eq. (4).

In order to quantify the differences in the calculation, the values obtained by the push-up method or “spectacle accommodation” “($Am_{push\text{-}up}$)” are compared with the values of ocular accommodation (Am_{eye}).

To perform the calculations we considered different values of neutralizing power of the lens (P_{NL}), associated with their corresponding values of refraction (R), and different values amplitude of accommodation of the eye [1].

$$P_{NL} = \frac{R}{1+\delta_V R} \tag{5}$$

The values shown in the tables of results correspond to P_{NL} ranging for +10D and −10D, in steps of 1D. The values of Am_{eye} ranged between 15.5D and 0.5D, corresponding to patients aged between 10 and 65 years approximately [20].

2.2. Experimental measurements

In order to determine if the theoretical results obtained for the calculation of amplitude of accommodation were in agreement with experimental values, the following experiment was conducted on a total of 8 eyes with an VA = 1 after their optical correction in patients between the ages of 20 and 25 years.

First, the position of the point first, slight, sustained blur with the neutralizing lens (np_D^G) was measured as described in Donder's method. On the one hand, this distance was used to calculate Donder's amplitude of accommodation ($Am_{push\text{-}up}$) (spectacle accommodation), that is, the dioptric value of this distance (Eq. (1)), and on the other, the amplitude of accommodation was found taking into account that the eye is really looking at the image of first blur through the lens (Am_{eye}) (ocular accommodation) (Eq. (4)).

Then, the near point of the uncorrected eye was determined ($np_{no\ lens}$), measuring the distance from the corneal vertex to the test object the moment the patient reports the first blur. In this way, the experimental measurement is not affected by the lens. This value was used to calculate the amplitude of accommodation of the eye ($Am_{no\ lens}$) in the following equation:

$$Am_{no\ lens} = R - \frac{1}{np_{no\ lens}} \tag{6}$$

Monocular measurements were taken for myopic refractions.

3. Results

3.1. Theoretical calculations

We compare the different methods of calculation, for a given value of R and Am_{eye}. To mathematically obtain the values of $Am_{push\text{-}up}$ from the values of Am_{eye}, the following calculations were performed: